Module 7 – Writing Names and Formulas

Prerequisites: Complete Module 6 before starting Module 7. The other prior modules are not necessary for Module 7.

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Lesson 7A: Naming Elements and Covalent Compounds

Pretest: If you think you know this topic, try the last letter of each question in Practice A and Practice B. If you get those right, skip the lesson.

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Systems for Naming Substances

In chemistry, substances are identified by both a unique name and a chemical formula. For names and formulas that both identify and differentiate substances, a **system** for writing formulas and names is required.

1. The names of some compounds are **non-systematic** but familiar: Water (H_2O) and ammonia (NH_3) are examples.
2. Historically, chemical substances have been divided into two broad categories. Compounds containing carbon comprise **organic chemistry**, which has its own system for naming compounds. All other substances are part of **inorganic chemistry**, which is the focus of most first-year chemistry courses.
3. Different types of inorganic substances have different naming systems. We will begin with the rules for elements, binary covalent compounds, ions, and binary ionic compounds.

Naming Elements

An element is a substance that contains of only one kind of atom. The **name** of an element is simply the name of its **atoms**.

Examples

- The element comprised of atoms with 20 protons is called **calcium**. Formulas of metals are written as if they are monatomic elements. The formula for the element calcium is written **Ca**.
- Chlorine atoms, at room temperature, are found in diatomic molecules. For the element chlorine, the formula is written $\mathbf{Cl_2}$.
- At room temperature, sulfur atoms tend to form molecules with 8 bonded atoms. For the elemental form of sulfur, the formula is written as $\mathbf{S_8}$.

Note that for elements, the formula easily distinguishes between monatomic, diatomic, or polyatomic structures, but their names do not. This is only an issue for a few of the elements, but for the millions of chemical compounds, a more systematic nomenclature (naming system) is needed.

Compounds

Most compounds can be classified as either **ionic** or **covalent**. These two types of compounds have different naming systems. To classify a compound as ionic or covalent, we must investigate its bonds.

Types of Bonds

1. In **covalent bonds**, electrons are *shared* between two atoms.
2. In **ionic bonds,** an atom (or group of atoms) has lost one or more electrons, and another atom (or group of atoms) has gained one or more electrons. The loss and gain of electrons results in charged particles (ions). The ions are bonded by the attraction of their opposite charges.
3. The following general rules will predict whether bonds are ionic or covalent in most cases.
   - A bond between two *non*metal atoms is a *covalent* bond.
   - A bond between a *metal* and a *non*metal is an *ionic* bond.

Types of Compounds

1. If a compound has *only* covalent bonds, it is classified as a **covalent compound.**
2. If a compound has *one* or more ionic bonds, it is classified as an **ionic compound.**

These rules mean that in most cases,

- a compound with *all non*metal atoms is a *covalent compound*.
- a compound with one or more *metal* atoms and one or more *non*metal atoms is an *ionic compound*. However, if the formula for the compound indicates that one or more polyatomic ions are present, the compound is most likely an ionic compound even if no metal atoms are present.

Covalent compounds exist as molecules. The bonds within molecules are strong compared to the attractions between molecules. Gas and liquid substances at room temperature are nearly always covalent compounds. Solids may be ionic or covalent compounds.

Ionic compounds are always solids at room temperature. Ionic compounds are composed of an array of ions bonded strongly by electrostatic attraction.

The above general rules do not cover all types of bonds and compounds, and there are many exceptions. However, they will give us a starting point for both naming compounds and writing formulas that indicate the composition and behavior of compounds.

Covalent Compounds

These are the 18 nonmetals:

			(H)	He
C	N	O	F	Ne
	P	S	Cl	Ar
		Se	Br	Kr
			I	Xe
			At	Rn

Recall that hydrogen is classified as a nonmetal, and that the last two columns are all nonmetals.

The six noble gases only rarely bond with other atoms. The remaining 12 nonmetal atoms nearly always form covalent bonds when they bond with each other.

The 12 nonmetals that tend to bond are a small percentage of the more than 100 elements. However, because

- covalent bonds are strong,
- the nonmetal atoms are relatively abundant on our planet, and
- the molecules in living systems that are of particular interest in science are based on a nonmetal (carbon),

a substantial percentage of the compounds studied in chemistry are covalent compounds.

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Practice A

On the problems below, use the type of periodic table that you are permitted to view on tests in your chemistry course. You should not need to consult the metal versus nonmetal charts found in these lessons, since they should be committed to memory. Answers are at the end of this lesson.

1. Label these bonds as ionic or covalent.

   a. Na—I b. C—Cl c. S—O d. Ca—F e. C—H f. K—Br

2. Label these compounds as ionic or covalent.

   a. CF_4 b. KCl c. CaH_2 d. H_2O e. NF_3 f. $NaCH_3O$

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Naming Binary Covalent Compounds.

Binary covalent compounds contain *two* different nonmetals.

The rules for naming binary covalent compounds are as follows.

1. The name contains two words.
2. Covalent compounds that contain hydrogen *begin* with *hydrogen*. Compounds that contain oxygen end in prefix-*oxide*. (This rule takes precedence over other rules below).
3. The *first root* word in the name is the name of the *element* that is in a column farther to the *left* in the periodic table.
4. For two nonmetals in the same column, the element farther down is named first.
5. The other element name has the root of the second word, with the suffix –*ide* added.
6. The number of each atom is given by a Greek prefix**.**

   mono- = 1 atom. (For the first element in the name, *mono-* is left off and assumed if no prefix is given. *Mono-* is included if it applies to the second word.)

di- = 2 atoms	*penta-* = 5 atoms	*octa-* = 8 atoms
tri- = 3 atoms	*hexa-* = 6 atoms	*nona-* = 9 atoms
tetra- = 4 atoms	*hepta-* = 7 atoms	*deca-* = 10 atoms

If a letter *o* or *a* at the end of a prefix is followed by a vowel as the first letter of the element name, the *o* or *a* in the prefix is *sometimes* omitted (both use and omission are allowed, and you will see such names both ways).

Examples. Use a periodic table and the above rules, name these.

Q1. What is the name of CS_2?

* * * * * (the * * * mean *cover* the answer below, *write* your answer, then check it.)

A1. Carbon is the element farther to the left in the periodic table, so carbon is the first root word in the name. For one carbon in the compound, the prefix would be *mono-*, but *mono-* is omitted if it applies to the first element. The first word in the name is simply carbon.

For the root of the second word, sulfur becomes sulfide. Since there are two sulfur atoms, the name of the compound is **carbon disulfide**.

Q2. What is the name of the combination of four fluorine atoms and two nitrogen atoms?

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A2. Nitrogen is more to the left in the periodic table, so the first root word is nitrogen. Since there are two nitrogen atoms, add the prefix *di-*. For the second word, the root fluorine becomes fluoride, and the prefix for four atoms is *tetra-*. The name for the compound is **dinitrogen tetrafluoride**.

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Flashcards

Cover the answers below, then check those which you can answer correctly and quickly. When done, make flashcards for the others (see Lesson 2D).

Run the new cards for several days in a row, then add them to the previous flashcards for quiz and test review.

One-way cards (with notch) — Back Side -- Answers

One-way cards (with notch)	Back Side -- Answers
Formula for elemental oxygen	O_2
A bond between a metal and nonmetal is	Usually ionic
A bond between two nonmetals is	Usually covalent
A covalent compound has	Shared electrons and only covalent bonds
An ionic compound has	One or more ionic bonds
A compound with all nonmetal atoms is usually	A covalent compound
Compounds with one or more metal atoms are	Ionic compounds

Two-way cards (with*out* notch):

Formula for ammonia = ?	Name of NH_3 = ?
Formula for carbon monoxide = ?	Name of CO = ?
Formula for dinitrogen tetrachloride = ?	Name of N_2Cl_4 = ?

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Practice B

Learn the rules, practice needed flashcards, then try every *other* problem. Wait a day, run the cards again, and try the remaining problems. If you need help in switching between the element name and symbol, add the name and symbol to your two-way flashcards.

1. Write the name for these combinations of nonmetals.

   a. Three chlorine plus one nitrogen.

   b. One sulfur and six fluorine.

   c. Two sulfurs and one silicon.

   d. Three chlorine and one iodine.

   e. One oxygen and two chlorines.

   f. One bromine and one iodine

2. Name these covalent compounds.

   a. HCl b. PI_3 c. SO_2 d. NO

3. Nonmetals often form several stable oxide combinations, including the combinations below. Name that compound!

   a. Five oxygen and two nitrogen

   b. 10 oxygen and four phosphorous

   c. NO_2 d. N_2O e. SO_3 f. Cl_2O_7

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ANSWERS

Practice A

1. a. Na—I **Ionic** b. C—Cl **Covalent** c. S—O **Covalent**
   d. Ca—F **Ionic** e. C—H **Covalent** f. K—Br **Ionic**

2. a. CF_4 **Covalent** b. KCl **Ionic** c. CaH_2 **Ionic**
   d. H_2O **Covalent** e. NF_3 **Covalent** f. CH_3ONa **Ionic**

   (All of the ionic compounds contain a metal atom.)

Practice B

1. a. Nitrogen is to the left, so it is the first word in the name. When the first word refers to a single atom, the prefix is omitted. For the second word, chlorine becomes chloride, and the prefix tri- is added. The name is **nitrogen trichloride.**

   b. Sulfur hexafluoride. c. Silicon disulfide d. Iodine trichloride (if in same column, name lower first) e. Dichlorine monoxide (oxygen is always last, drop last mono *o*) f. Iodine monobromide

2. a. Hydrogen chloride b. Phosphorous triiodide c. Sulfur dioxide d. Nitrogen monoxide

3. a. Dinitrogen pentoxide (or pentaoxide) b. tetraphosphorous decaoxide c. Nitrogen dioxide
   d. Dinitrogen monoxide e. Sulfur trioxide f. Dichlorine heptaoxide (or heptoxide).

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Lesson 7B: Naming Ions

Prerequisites: Complete Module 6 and Lesson 7A before starting this lesson.

Pretest: If you think you know this topic, try several problems at the end of this lesson. If you complete them all correctly, you may skip the lesson.

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Ions

In ionic compounds, the constituent particles are *ions*, particles with an electrical charge.

In most first-year chemistry courses you will be asked to memorize the names and symbols for more than 50 frequently encountered ions. This task is simplified by the patterns for ion charges that are found in the periodic table. Learning these rules and patterns will help you to speak the language of chemistry.

Categories of Ions

Ions can be separated into categories that determine how the ion is written in chemical formulas and how the ion is named.

1. All ions are either positive or negative.
   - Positive ions are termed **cations** (pronounced KAT-eye-ons). The charges on positive ions can be 1+, 2+, 3+, or 4+.
   - Negative ions are termed **anions** (pronounced ANN-eye-ons). The charges on negative ions can be 1–, 2–, or 3–.
2. All ions are either **monatomic** or **polyatomic.**
   - A monatomic ion is composed of a single atom. Monatomic ions can have positive or negative charges, and single or multiple charges.

     Examples of monatomic ions are Na^+, Al^{3+}, Cl^-, and S^{2-}.
   - A polyatomic ion is a particle that has two or more covalently bonded atoms and an overall electric charge.

     Examples of polyatomic ions are OH^-, Hg_2^{2+}, NH_4^+, and SO_4^{2-}.

Ions of Hydrogen

Hydrogen has unique characteristics. It is classified as a nonmetal, and in most of its compounds hydrogen bonds covalently. In compounds classified as acids, hydrogen can form H^+ ions (protons). When bonded to metal atoms, hydrogen behaves as a hydride ion (H^-).

The Structure and Charge of Metal Ions

A periodic table will be helpful when learning the following rules for the charges on metal ions.

More than 70% of the naturally occurring elements in the periodic table are metal atoms. Neutral metal atoms tend to lose electrons to form positive ions. In ionic compounds, *metal* atoms are nearly always *monatomic cations*.

- In compounds with metal atoms and one or more nonmetal atoms, the metal atoms always have a positive charge. The charge can be 1+, 2+, 3+, or 4+.
- With the exception of mercurous (Hg_2^{2+}) ion, all of the frequently encountered metal ions are monatomic: *single* metal atoms that have lost one or more electrons.

  Examples of metal ions are Na^+, Mg^{2+}, Al^{3+}, and Sn^{4+}.

All metals form at least one positive ion. Some metals form two or more stable ions. In some cases, the charge (or possible charges) on a metal ion can be predicted from the position of the metal in the periodic table.

Metal Ions With One Charge

Metals in the *first two* columns of the periodic table form only one ion. The charge on that ion is easy to predict.

- All metals in column *one* (the alkali metals) form ions that are single atoms with a **1+** charge: Li^+, Na^+, K^+, Rb^+, Cs^+, and Fr^+.
- All metals in column *two* form ions that are single atoms with a **2+** charge: Be^{2+}, Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}, and Ra^{2+}.

The charges on metal ions in the remainder of the periodic table are more difficult to predict. Additional rules that help in predicting ion charge will be learned when electron configuration is studied in later parts of your course.

In order to solve problems initially, most courses require that the charge on certain frequently encountered metal ions to the right of the first two columns in the periodic table be memorized. The rules below will help with that process.

Most metals to the right of the first two columns form two or more stable ions, but some form only one. The following rule should be memorized.

- Metals to the right of the first two columns that form only *one* stable ion include Ni^{2+}, Ag^+, Zn^{2+}, Cd^{2+}, and Al^{3+}.

For help in remembering this group, note the position of these metals in the periodic table.

Other metal atoms may tend to form only one ion, but those metals are not frequently encountered in labs or problems in first-year chemistry.

Naming Metal Ions

In naming metal ions, there is one rule for metals that form only one ion, and another for metals that form two or more stable ions.

1. If a metal forms only *one* stable ion, the ion name is the element name.

   Examples: Na^+ is a sodium ion. Al^{3+} is an aluminum ion.

   This rule applies to

   - metal ions in columns one and two, plus
   - the additional five metal ions listed above, plus
   - additional ions that may be studied in later parts of first-year chemistry.

2. For metals that form *two* or more positive ions, the **systematic name** (or *modern* name) of the ion is the element name followed by a roman numeral in parentheses that states the positive charge.

   Examples: Fe^{2+} is named iron(II) and Fe^{3+} is named iron(III)

3. Metals that form *two* different positive ions and were "known to the ancients" also have **common names** for their ions.

In common names, the lower charged ion uses the Latin root of the element name plus the suffix *–ous*. The higher-charged ion uses the Latin root plus the suffix *–ic.*

For metal ions, the systematic (roman numeral) names are preferred, but the common names are often used.

Most courses require that the names and symbols for the following 10 ions, and perhaps others, be memorized.

Ion Symbol	Systematic Ion Name	Common Ion Name
Cu^{+}	copper(I)	cuprous
Cu^{2+}	copper(II)	cupric
Fe^{2+}	iron(II)	ferrous
Fe^{3+}	iron(III)	ferric
Sn^{2+}	tin(II)	stannous
Sn^{4+}	tin(IV)	stannic
Hg_2^{2+}	mercury(I)	mercurous
Hg^{2+}	mercury(II)	mercuric

Lead also forms two ions. Pb^{2+} is named lead(II), and Pb^{4+} is named lead(IV). The common names plumbous and plumbic are rarely used.

<u>When to Include Roman Numerals In Systematic Names</u>

The rule is: Do *not* use roman numerals in systematic names for metal ions that can form only *one* stable ion: ions for atoms in the first two columns, plus Ni^{2+}, Ag^{+}, Zn^{2+}, Cd^{2+}, and Al^{3+}.

For the ion of a metal to the right of column 2, if you are uncertain that you remember those last 5 ions correctly, adding the roman numeral, such as using nickel(II) for Ni^{2+}, may be acceptable in your course.

<u>Summary: Metal Ion Rules</u>

- All metal ions are positive. Except for Hg_2^{2+}, all metal atoms are monatomic.
- In column one, all elements tend to form 1+ ions.
- In column two, all elements tend to form 2+ ions.
- For the metals to the right of column 2, five metals form only one ion: Ni^{2+}, Ag^{+}, Zn^{2+}, Cd^{2+}, and Al^{3+}. Assume that the others form more than one ion.
- If a metal forms only one ion, the ion name is the element name.
- If a metal forms **more** than one ion, the systematic ion name is the element name followed by a roman numeral in parentheses showing the positive charge of the ion.

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Flashcards: Using the flashcard steps in Lesson 2D, make any of these that you cannot answer from memory.

One-way cards (with notch)	Back Side -- Answers
cation	positive ion
anion	negative ion
Monatomic ion	one atom with a charge
Polyatomic ion	2 or more bonded atoms with an overall charge
All metal ions (except mercurous) are	Monatomic – contain only one atom
The charge on a metal ion is always	positive
Column one ions have what charge?	+1
Column two ions have what charge?	+2
When is () in ion name needed?	In systematic names, if >1 ion is found for the metal
In the systematic names for metal ions, which do not need (roman numerals) to show their charge?	Columns 1 and 2, plus Ni^{2+}, Ag^{+}, Zn^{2+}, Cd^{2+}, and Al^{3+}

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Practice A: Use a periodic table. Memorize the rules, ion symbols, and names in the section above *before* doing the problems. On multi-part questions, do every other part today, and the rest during your next study session.

1. Add a charge to show the symbol for the stable ion that these elements form.

   a. Ba b. Al c. Rb d. Na e. Zn f. Ag

2. Write the symbols for these ions.

   a. Cadmium ion b. Lithium ion c. Hydride ion d. Calcium ion

3. Which ions in Problems 1 and 2 are anions?
4. Write the name and symbol for a polyatomic metal ion often encountered.
5. Fill in the blanks.

Ion Symbol	Systematic Ion Name	Common Ion Name
		Stannic
		Cupric
	Iron(III)	
	Copper(I)	
Fe^{2+}		

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Monatomic Anions

In addition to H^- (hydride), there are 8 monatomic anions often encountered in first-year chemistry. Their names and symbols should be memorized.

- Four are halides: fluoride, chloride, bromide, and iodide (F^-, Cl^-, Br^-, and I^-).
- Four others are oxide (O^{2-}), sulfide (S^{2-}), nitride (N^{3-}), and phosphide (P^{3-}).

For monatomic anions, the name is the root of the element name followed by ***-ide.***

Note that the charge on the monatomic anions is always 8 minus the group number.

The position of these elements in the periodic table will help in remembering their ion charges (see the *General Characteristics* table in Lesson 6D.)

Polyatomic Ions

A polyatomic ion is a particle that both has two or more atoms held together by covalent bonds and has an overall electrical charge. In polyatomic ions, the total number of protons and electrons in the particle is not equal.

An example of a polyatomic ion is the hydroxide ion, OH^-. One way to make this ion is to start with a neutral water molecule H—O—H, which has 1+8+1 = 10 protons and 10 balancing electrons, and to take away an H^+ ion.

The result is a particle composed of two atoms with a total of 9 protons and 10 electrons. Overall, the particle has a negative charge. The negative charge behaves as if it is attached to the oxygen. A structural formula for the hydroxide ion is

$$H-O^-$$

Polyatomic ions will be considered in more detail when studying the three-dimensional structure of particles. At this point, our interest is the ratios in which ions combine. For that purpose, it may help to think of a monatomic ion as a charge that has one atom attached, and a polyatomic ion as a charge with several atoms attached.

The *charges* on the ions determine the *ratios* of the ions in compounds. The number of atoms in an ion is a factor in writing the formula for the compound, but it does not affect the ratio of the ions in the compound.

Polyatomic Cations

Three polyatomic cations with names and symbols that should be memorized are the NH_4^+ (ammonium), H_3O^+ (hydronium), and Hg_2^{2+} (mercury(I) or mercurous) ions.

Oxoanions

Polyatomic ions with negative charges that contain oxygen are termed **oxoanions**.

Oxoanions are often part of a *series* of ions that has one *common* atom, the same charge, and different numbers of oxygen atoms.

Example: Nitrate ion = NO_3^- , nitrite ion = NO_2^-

The names and symbols for most oxoanions can be determined from the following rules.

Oxoanion Naming System.

1. When there are *two* oxyanions, the ion named root-*ite* has the same charge and one less oxygen than the root-*ate*.

Example: Sulf**ate** is SO_4^{2-} . Sulf**ite** is SO_3^{2-} .

2. If there are *more* than two oxyanions in a series, the
   - *per*–root–*ate* ion has X oxygen atoms:
   - root-*ate* ion has the same charge and one fewer oxygens;
   - root-*ite* ion has the same charge and 2 fewer oxygens;
   - *hypo*-root-*ite* ion has the same charge and 3 fewer oxygens.

Example: From the above table, memorize that the ClO_4^{-} ion is named ***per***chlor*ate*. Then,

- ClO_3^{-} is chlor**ate**;
- ClO_2^{-} is chlor**ite**;
- ClO^{-} is **hypo**chlor**ite**.

A strategy that will simplify naming these ions is to memorize the formula for *one* ion in a series, then to write out the rest by logic as needed. With practice, this process will become automatic.

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Memorizing the Ion Names and Formulas

In most courses, you will be asked to memorize the names and formulas for a list of frequently encountered ions. Even if it is not required, doing so will speed your work and improve your understanding of problems assigned in chemistry.

The following set of flashcards is information that you will rely on heavily for the remainder of the year.

You may want to use a unique card color to identify these as the *ion* cards, *or* add the word *ion* for clarity after each ion name.

Your course may not require that you know the "latin" names for the metal ions that have more than one possible charge, but learning those names and charges will help you to recognize which possible charges are likely to be found for those metal ions.

Make these "two-way" flashcards following the procedure in Lesson 2D. You will need to be able to translate in *both* directions between the names and the ion formulas.

Cover the formula, and put a check if you are certain of the formula from the name. Then cover the names and put a check if you know the name from the formula. You may omit making flashcards for names and formulas that you already know well in both directions.

For a large number of new flashcards, allow yourself several days of practice to learn them. In the beginning, writing and saying the answers will speed your progress.

Two-way cards (with*out* notch):

CH_3COO^-	acetate
CN^-	cyanide
OH^-	hydroxide
NO_3^-	nitrate
MnO_4^-	permanganate
CO_3^{2-}	carbonate
HCO_3^-	hydrogen carbonate
CrO_4^{2-}	chromate
$Cr_2O_7^{2-}$	dichromate
PO_4^{3-}	phosphate
SO_4^{2-}	sulfate
SO_3^{2-}	sulfite
Na^+	sodium ion
K^+	potassium ion
Al^{3+}	aluminum ion
F^-	fluoride
Cl^-	chloride
Br^-	bromide
I^-	iodide
Ca^{2+}	calcium ion
Ba^{2+}	barium ion

Two-way cards (with*out* notch):

Cu^+	cuprous
Cu^{2+}	cupric
Fe^{2+}	ferrous
Fe^{3+}	ferric
Sn^{2+}	stannous
Sn^{4+}	stannic
Hg_2^{2+}	mercurous or mercury (I)
Hg^{2+}	mercuric
O^{2-}	oxide
S^{2-}	sulfide
N^{3-}	nitride
P^{3-}	phosphide
ClO_4^-	perchlorate
ClO_3^-	chlorate
ClO_2^-	chlorite
ClO^-	hypochlorite
H^+	hydrogen ion
H^-	hydride
Mg^{2+}	magnesium ion
NH_4^+	ammonium
H_3O^+	hydronium

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Practice B: Memorize the ion symbols and names in the section above, *then* try these problems. Work in your notebook. Repeat these again after a few days of flashcard practice.

1. In this chart of ions, from memory, add *charges*, *names*, and ion *formulas*.

Symbol	**Ion name**
	acetate
CN	
	silver
	hydroxide
Al	
ClO_4	
	nitrate
	sodium
F	

CO_3	
	radium
MnO_4	
CrO_4	
K	
	dichromate
PO_4	
	sulfate
	sulfide
Ba	

2. Circle the **poly**atomic ion symbols in the left column of Problem 1 above.
3. If NO_3^- is a nitrate ion, what is the symbol for a nitrite ion?
4. Complete this table for the series of oxoanions containing bromine.

Ion name	**Ion Symbol**
Per_______________	_______________
___________________________	BrO_3^-
Bromite	__________________
Hypo_________________	___________________

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ANSWERS

Practice A

1. a. Ba^{2+} b. Al^{3+} c. Rb^{+} d. Na^{+} e. Zn^{2+} f. Ag^{+}
2. a. Cd^{2+} b. Li^{+} c. H^{-} d. Ca^{2+} 3. Only the hydride ion (H^{-}). 4. Hg_2^{2+}

5.

Ion Symbol	Systematic Ion Name	Common Name
Sn^{4+}	**tin(IV)**	stannic
Cu^{2+}	**copper(II)**	cupric
Fe^{3+}	iron(III)	**ferric**
Cu^{+}	copper(I)	**cuprous**
Fe^{2+}	**iron(II)**	**ferrous**

Practice B

1,2.

Symbol	Ion name
CH_3COO^-	acetate
CN^-	**cyanide**
Ag^+	silver
OH^-	hydroxide
Al^{3+}	**aluminum**
ClO_4^-	**perchlorate**
NO_3^-	nitrate
Na^+	sodium
F^-	**fluorine**

CO_3^{2-}	**carbonate**
Ra^{2+}	radium
MnO_4^-	**permanganate**
CrO_4^{2-}	**chromate**
K^+	**potassium**
$Cr_2O_7^{2-}$	dichromate
PO_4^{3-}	**phosphate**
SO_4^{2-}	sulfate
S^{2-}	sulfide
Ba^{2+}	**barium**

3. **NO_2^-**

4.

Ion name	Ion Symbol
Per**bromate**	**BrO_4^-**
Bromate	BrO_3^-
Bromite	**BrO_2^-**
Hypo**bromite**	**BrO^-**

Lesson 7C: Names and Formulas for Ionic Compounds

Pretest: Answers are at the end of the lesson. If you get these right, you may skip the lesson.

1. Name $Pb_3(PO_4)_2$ 2. Write formulas for a. tin(IV) chlorate b. radium nitrate.

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Ionic Compounds: Fundamentals

Positive and negative ions combine to form ionic compounds. Ionic compounds must have both positive and negative ions.

There is only *one ratio* possible for the ions in a compound. The ions must combine in ratios that guarantee electrical neutrality. This means that the *charges* in any ionic substance must *balance*. The overall charge of any combination of ions must be zero.

Names and Formulas

The composition of an ionic compound can be expressed in three ways.

- In a **name**; Example: ammonium phosphate
- As a **solid** formula; Example: $(NH_4)_3PO_4$
- As balanced, **separated ions**. Example: $3\ NH_4^+ + 1\ PO_4^{3-}$.

To solve chemistry problems, given any one of these expressions, you need to be able to write the other two.

Ionic compounds can initially be confusing because their names and solid formulas do not clearly identify the *charges* on the ions. The key to writing correct names and solid formulas is to first write the *separated-ions* formulas that show clearly the number and the formulas of the ions, including their charges.

For ionic compounds, the fundamental rules for writing names and formulas are:

- Always write the *separated-ions* formula *first*.
- Add *coefficients* that balance the *charges*.

Balancing Separated Ions

In all combinations of ions, whether in solids, melted, or dissolved in water, the total charges on the ions must balance. In problems, you will often be asked to determine the *ratios* that balance the charges. The way to find those ratios is to write a balanced *separated-ions* formula for the compound. Let's learn the method with an example.

Q. Find the ratio that balances the charges when S^{2-} and Na^{+} combine.

Cover the answer below, try this problem using these steps, *then* check your answer.

Step 1: Write the symbols for the two ions in the compound, with their charges, separated by a + sign. It is preferred to put the positive ion first.

Step 2: Coefficients are numbers written in *front* of ion or particle symbols. In all ion combinations, (coefficient *times* charge of cation) must equal (coefficient *times* charge of anion).

Add the whole-number **coefficients** in front of the ion formulas that *make* the positive and negative charges balance.

In balancing, you *cannot* change the symbol or the stated charge of an ion. The only change allowed is to add coefficients.

Step 3: Reduce the coefficients to the *lowest* whole-number ratios.

* * * * *

Answer Step 1: $Na^{+} + S^{2-}$

Step 2: $\mathbf{2}\ Na^{+} + \mathbf{1}\ S^{2-}$ This is the *separated*-ions formula.

The coefficients that balance the charges show the ratios in which the ions must exist in the compound.

Step 3: 2 and 1 are the lowest whole-number ratios.

There *must* be *two* sodium ions for every *one* sulfide ion. Why? For the charges, (2 times 1+ = 2+) balances (1 times 2− = 2−). In ion combinations, the ions are always present in ratios so that the total positive and negative *charges* balance.

Only one set of coefficient *ratios* will balance the charges.

Try another. Cover the answer below, then try this question using the steps above.

Q. Add coefficients so that the charges balance: ___ Al^{3+} + ___ SO_4^{2-}

* * * * *

Answer: An easy way to find the coefficients is to make the coefficient of each ion equal to the *number* of *charges* of the *other* ion.

$$\mathbf{2}\ Al^{3+} + \mathbf{3}\ SO_4^{2-}$$

For these ions, (2 times +3 = +6) balances (3 times −2 = −6). In an ionic compound, the total positives and total negatives must balance.

However, when balancing charge when using this method, you must often adjust the coefficients so that the *final* coefficients are the *lowest* whole-number ratios.

Try this problem.

Q. Add proper coefficients: ____ Ba^{2+} + ____ SO_4^{2-}

* * * * *

Answer

If balancing produces a ratio of

2 Ba^{2+} + **2** SO_4^{2-} , write the *final* coefficients as **1** Ba^{2+} + **1** SO_4^{2-} .

When balancing ions, make the coefficients the *lowest whole-number* ratios.

* * * * *

Practice A: Add lowest-whole-number coefficients to make these separated ions balanced for charge. After every two, check your answers at the end of the lesson.

1. ____ Na^{+} + ____ Cl^{-}
2. ____ Ca^{+2} + ____ Br^{-}
3. Mg^{+2} + SO_4^{2-}
4. Cl^{-} + Al^{3+}
5. NH_4^{+} + CH_3COO^{-}
6. In^{3+} + CO_3^{2-}
7. Al^{3+} + PO_4^{3-}
8. HPO_4^{2-} + In^{3+}

* * * * *

Writing the Separated Ions from Names

To write the separated ions from the *name* of an ionic compound, use these steps.

Step 1: Write the symbols for the two named ions, with their charges, separated by a + sign. The first word in the name is always the positive ion.

Step 2: Add lowest-whole-number coefficients to balance the charges.

Try those the steps on this problem:

Q. Write a balanced separated-ions formula for aluminum carbonate.

* * * * *

Answer: Step 1: Aluminum carbonate → Al^{3+} + CO_3^{2-}

Step 2: Aluminum carbonate → **2** Al^{3+} + **3** CO_3^{2-}

The separated-ions formula shows clearly what the name does not. In aluminum carbonate, there must be 2 aluminum ions for every 3 carbonate ions.

When writing separated ions, write the charge *high*, the subscript *low*, and the coefficient at the *same* level as the symbol.

* * * * *

Practice B

Write balanced separated-ions formula for these ionic compounds. You may use a periodic table, but otherwise write the ion formulas from memory. If needed, run your ion flashcards one more time. Check answers as you go.

1. Sodium hydroxide →

2. Aluminum chloride →

3. Rubidium sulfite →

4. Ferric nitrate →

5. Lead(IV) phosphate →

6. Calcium chlorate →

* * * * *

Writing Solid Formulas From Names

In ionic solid formulas, charges are hidden, but charges must balance. The key to writing a correct solid formula is to write the balanced *separated*-ions first, so that you can see and balance the charges.

To write a *solid* formula from the name of an ionic compound, use these steps.

1. Based on the name, write the *separated* ions. Add lowest whole number coefficients to balance charge. Then, to the right, draw an arrow → .
2. After the →, write the two ion symbols, positive ion first, with a small space between them. Include any *subscripts* that are part of the ion symbol, but *no* charges or coefficients.
3. For the ion symbols written after the arrow, **p**ut **p**arentheses () around a **p**olyatomic ion *if* its coefficient in the separated-ions formula is more than 1.
4. Add *subscripts* after each symbol on the right. The subscript will be the same as the coefficient in front of that ion in the *separated-ions* formula.

   Omit subscripts of 1. For polyatomic ions, write the coefficients as subscripts *outside* and *after* the parentheses.

Apply those four steps to this example.

Q. Write the solid formula for potassium sulfide.

* * * * *

Answer

1: Write the separated ions first. Potassium sulfide is $2\ K^+ + 1\ S^{2-}$

2: Write the symbols without coefficients or charges. $2\ K^+ + 1\ S^{2-}$ → **K S**

3: Since both K and S ions are monatomic, add no parentheses.

4: The K coefficient becomes a solid formula subscript: $\mathbf{2}\ K^+ + 1\ S^{2-}$ → $\mathbf{K_2S}$

The sulfide subscript of one is omitted as "understood."

The *solid* formula for potassium sulfide is $\mathbf{K_2S}$.

* * * * *

Try another using the same steps.

Q. Write the solid formula for magnesium phosphate.

* * * * *

Answer

1: Write the balanced separated ions. Magnesium phosphate → **3** Mg^{2+} + **2** PO_4^{3-}

2: Write symbols without coefficients or charges. **3** Mg^{2+} + **2** PO_4^{3-} → **Mg $\mathbf{PO_4}$**

3: Since Mg^{2+} is *mon*atomic (just one atom), it is not placed in parentheses.

Phosphate is *both poly*atomic *and* we need **>1**, so add **( )** . **Mg ($\mathbf{PO_4}$)**

4: The separated coefficient of the Mg ion becomes its solid subscript. **$\mathbf{Mg_3(PO_4)}$**

The phosphate ion's separated coefficient becomes its solid subscript. **$\mathbf{Mg_3(PO_4)_2}$**

$\mathbf{Mg_3(PO_4)_2}$ is the solid formula for magnesium phosphate.

It is helpful to recite the following rule for ionic solid formulas until it is memorized.

> ➢ ***P*ut *p*aren**theses around ***p*oly**atomic ions -- *if* you need more than one.

* * * * *

Practice C: As you go, check the answers at the end of the lesson. You may want to do half of the lettered parts today, and the rest during you next study session.

1. Circle the polyatomic ions.

   a. Na^{+} b. NH_4^{+} c. CH_3COO^{-} d. Ca^{2+} e. OH^{-}

2. When do you need parentheses? Write the rule from memory.

3. Write solid formulas for these ion combinations.

   a. 2 K^{+} + 1 CrO_4^{2-} →

   b. 2 NH_4^{+} + 1 S^{2-} →

   c. 1 SO_3^{2-} + 1 Sr^{2+} →

4. Balance these separated ions for charge, then write solid formulas.

   a. Cs^{+} + N^{3-} →

   b. $Cr_2O_7^{2-}$ + Ca^{2+} →

   c. Sn^{4+} + SO_4^{2-} →

5. From these names, write the separated-ions formula, then the solid formula.

   a. Ammonium sulfite →

   b. Potassium permanganate →

   c. Calcium hypochlorite →

   d. Sodium hydrogen carbonate →

6. Write the solid formula.

   a. Stannous fluoride →

   b. Calcium hydroxide →

   c. Radium acetate →

* * * * *

Writing Separated Ions From Solid Formulas

When placed in water, most ionic solids dissolve to some extent. The dissolved ions separate and move about in the solution.

This dissolving process can be represented by a chemical equation that has a solid on the left and the separated ions on the right. For example, when solid sodium phosphate dissolves in water, the equation is

$$Na_3PO_4\ (s) \xrightarrow{H_2O} 3\ Na^+(aq)\ +\ 1\ PO_4^{3-}(aq)$$

The (s) is an abbreviation for *solid*, and the (aq) is an abbreviation for **aqueous**, which means "dissolved in water."

An equation for ion separation must balance atoms, balance charge, and result in the correct formulas for the ions that are actually found in the solution.

In equations for an ionic solid separating into its ions, some subscripts in the solid formula become coefficients in the separated ions, and some do not. In the equation above, the subscript 3 became a coefficient, but the subscripts 1 and 4 did not. To correctly separate solid formulas into ions, you must be able to recognize the ions in the solid formula.

Cover the answer below, try this example, then check the answer for tips that will make this process easier.

Q. Write the equation for the ionic solid Cu_2CO_3 separating into its ions.

* * * * *

Answer: Follow these steps in going from a solid formula to separated ions.

Step 1: Decide the *negative* ion's charge and coefficient first.

The first ion in a solid formula is always the positive ion, but many metal ions can have two possible positive charges. Most negative ions only have one likely charge, and that charge will decide the positive ion's charge, so do the negative ion first.

For Cu_2CO_3, the negative ion is CO_3, which always has a 2– charge.

This step temporarily splits the solid formula into **Cu_2** and 1 CO_3^{2-}.

Step 2: Decide the positive ion's charge and coefficients.

Given Cu_2 and CO_3^{2-}, the positive part must include **2** copper atoms *and* must have a total **2+** charge to balance the charge of CO_3^{2-}.

So **Cu_2**, in the separated-ions formula, must be *either* **1** Cu_2^{2+} ***or*** **2** Cu^+.

Both possibilities balance atoms and charge. Which is correct? Recall that

All *metal* ions are *mon*atomic (except Hg_2^{2+} (mercury(I) ion)).

This means that Cu^+ must be the ion that forms, since Cu_2^{2+} is polyatomic. Because most metal ions are monatomic, a solid formula with a metal ion will separate

$$M_X\text{Anion} \rightarrow X\,M^{+?} + \text{Anion}$$ (*unless* the metal ion is Hg_2^{2+}).

You also know that Cu^+ is the copper(I) ion that was previously memorized because it is frequently encountered.

Both rules lead us to predict that the equation for ion separation is

$$\mathbf{Cu_2CO_3 \rightarrow 2\,Cu^+ + 1\ CO_3^{2-}}$$

Copper can also be a Cu^{2+} ion, but in the formula above, there is only one carbonate, and carbonate always has a 2– charge. Two Cu^{2+} ions cannot balance the single carbonate.

Step 3: Check. Make sure that the charges balance. Make sure that the number of atoms of each kind is the same on both sides. The equation must also make sense going backwards, from the separated to the solid formula.

Try another.

Q2. Write the equation for the ionic solid **$(NH_4)_2S$** dissolving to form ions.

* * * * *

Answer

- In a solid formula, parentheses are placed around polyatomic ions. When you write the separated ions, a subscript after parentheses *always* becomes the polyatomic ion's *coefficient*.

  You would therefore split the formula **$(NH_4)_2S$ → 2 NH_4 + 1 S**

- Assign the charges that these ions prefer. $(NH_4)_2S$ → 2 NH_4^+ + 1 S^{2-}
- Check. In the separated formula, the charges must balance. They do.

  Going backwards, separated ions must make the solid formula. They do.

Keep up your practice, for 15-20 minutes a day, with your *ion* name and formula *flashcards* (Lesson 7B). Identifying ions without consulting a table will be essential in the more complex problems ahead.

* * * * *

Practice D

If you have not already done so today, run your ion flashcards in both directions, then try these. To take advantage of the "spacing effect"(Lesson 2D), do half of the lettered parts below today, and the rest during you next study session.

1. Finish balancing by adding ions, coefficients, and charges.

   a. $PbCO_3$ → Pb + 1 CO_3^{2-}

   b. Hg_2SO_4 → Hg_2 +

2. Write equations for these ionic solids separating into ions.

   a. KOH →

   b. $CuCH_3COO$ →

   c. $Fe_3(PO_4)_2$ →

   d. Ag_2CO_3 →

   e. NH_4OBr →

   f. $Mn(OH)_2$ →

* * * * *

Naming Ionic Compounds

From a solid or a separated-ions formula, writing the *name* is easy.

Step 1: Write the separated-ions formula.

Step 2: Write the *name* of the positive ion in the formula.

Step 3. Write the name of the negative ion.

That's it! In ionic compounds, the name ignores the number of ions inside. Simply name which ions are in the compound , with the positive ion named first. Try this problem.

Q. What is the name of K_2CO_3?

* * * * *

Answer

$K_2CO_3 \rightarrow$ 2 $\mathbf{K^+}$ + 1 $\mathbf{CO_3^{2-}}$; the name is potassium carbonate.

With time, you will be able to convert solid formulas to compound names without writing the separated ions, but the only way to develop this accurate intuition is by practice.

* * * * *

Practice E: If you are unsure of an answer, check it before continuing.

1. Return to Practice D and name each compound.
2. In Practice C, Problems 3 and 4, name each compound.
3. Would CBr_4 be named carbon bromide or carbon tetrabromide? Why?
4. Name these ionic and covalent compounds. Try doing half today and half during your next study session.

a. $CaBr_2$ b. NCl_3 c. NaH d. $CuCl_2$

e. $RbClO_4$ f. KOI g. Li_3P h. PbO

i. NH_4BrO_2 j. SO_2 k. $CaSO_3$ l. P_4S_3

* * * * *

Flashcards: Add these to your collection.

One-way cards (with notch)	Back Side -- Answers
What must be true in all ionic substances?	Total **+** charges = total **—** charges Must be electrically neutral
What numbers do you add to balance separated ions?	coefficients
To understand ionic compounds:	Write the *separated*-ion formulas
When are parentheses needed in formulas?	In *solid* formulas, put parentheses around polyatomic ions -- *if* you need **>1**
In separated-ion formulas, what do the coefficients tell you?	The ratio in which the ions must be present to balance atoms and charge

* * * * *

Practice F: Combining Ions Worksheet

Fill in the blanks. Do half today and the rest during your next study session. Check answers at the end of the lesson.

Ionic Compound NAME	SEPARATED Ions	SOLID Formula
• Name by ion names • Must be two or more words • Put name of + ion first	• Charges must show • Charges must balance • Charges may flow • Coefficients tell ratio of ions	• Positive ion first • Charges balance, but don't show • Put () around polyatomic ions IF you need >1
Sodium chloride	1 Na^{+} + 1 Cl^{-}	NaCl
	2 Al^{3+} + 3 SO_3^{2-}	$Al_2(SO_3)_3$
Lithium carbonate		
Potassium hydroxide		
	___ Ag^{+} + ___ NO_3^{-}	
	___ NH_4^{+} + ___ SO_4^{2-}	
		$FeBr_2$
		$Fe_2(SO_4)_3$
Cuprous chloride		
Tin(II) fluoride		
	__ Al^{3+} + __ $Cr_2O_7^{2-}$	
		K_2CrO_4
		$CaCO_3$
Aluminum phosphate		

ANSWERS

Pretest: 1. Lead(II) phosphate 2a. $Sn(ClO_3)_4$ 2b. $Ra(NO_3)_2$

Practice A

1. **1** Na^+ + **1** $Cl^—$
2. **1** Ca^{+2} + **2** $Br^—$
3. **1** Mg^{+2} + **1** $SO_4^{2—}$
4. **3** $Cl^—$ + **1** Al^{3+}
5. **1** NH_4^+ + **1** $CH_3COO^—$
6. **2** In^{3+} + **3** $CO_3^{2—}$
7. **1** Al^{3+} + **1** $PO_4^{3—}$
8. **3** $HPO_4^{2—}$ + **2** In^{3+}

Practice B

1. Sodium hydroxide → **1 Na^+ + 1 $OH^—$**
2. Aluminum chloride → **1 Al^{3+} + 3 $Cl^—$**
3. Rubidium sulfite → **2 Rb^+ + 1 $SO_3^{2—}$**
4. Ferric nitrate → **1 Fe^{3+} + 3 $NO_3^—$**
5. Lead(IV) phosphate → **3 Pb^{4+} + 4 $PO_4^{3—}$**
6. Calcium Chlorate → **1 Ca^{2+} + 2 $ClO_3^—$**

Practice C

1. The polyatomic ions: **b. NH_4^+** **c. $CH_3COO^—$** **e. $OH^—$**
2. For ionic solid formulas, put parentheses around polyatomic ions IF you need more than one.

3a. **2** K^+ + **1** $CrO_4^{2—}$ → **K_2CrO_4**

3b. **2** NH_4^+ + **1** $S^{2—}$ → **$(NH_4)_2S$**

3c. **1** $SO_3^{2—}$ + **1** Sr^{2+} → **$SrSO_3$**

4a. **3** Cs^+ + **1** $N^{3—}$ → **Cs_3N**

4b. **1** $Cr_2O_7^{2—}$ + **1** Ca^{2+} → **$CaCr_2O_7$**

4c. **1** Sn^{4+} + **2** $SO_4^{2—}$ → **$Sn(SO_4)_2$**

5a. **2** NH_4^+ + **1** $SO_3^{2—}$ → **$(NH_4)_2SO_3$**

5b. **1** K^+ + **1** $MnO_4^—$ → **$KMnO_4$**

5c. **1** Ca^{2+} + **2** $OCl^—$ → **$Ca(ClO)_2$**

5d. **1** Na^+ + **1** $HCO_3^—$ → **$NaHCO_3$**

6. Write balanced, separated ions first to help with the solid formula.
   a. Stannous fluoride → 1 Sn^{2+} + 2 $F^—$ → **SnF_2**
   b. Calcium hydroxide → 1 Ca^{2+} + 2 $OH^—$ → **$Ca(OH)_2$**
   c. Radium acetate → 1 Ra^{2+} + 2 $CH_3COO^—$ → **$Ra(CH_3COO)_2$**

Practice D and E

1. a. $PbCO_3$ → **1** Pb^{2+} + 1 $CO_3^{2—}$ **(Lead(II) carbonate)**
   b. Hg_2SO_4 → 1 Hg_2^{2+} + **1 $SO_4^{2—}$** **(Mercurous sulfate** or **Mercury(I) sulfate)**
2. a. KOH → **1 K^+ + 1 $OH^—$** **(Potassium hydroxide)**
   b. $CuCH_3COO$ → **1 Cu^+ + 1 $CH_3COO^—$** **(Copper(I) acetate** or **cuprous acetate)**
   c. $Fe_3(PO_4)_2$ → **3 Fe^{2+} + 2 $PO_4^{3—}$** **(Iron(II) phosphate** or **ferrous phosphate)**
   d. Ag_2CO_3 → **2 Ag^+ + 1 $CO_3^{2—}$** **(Silver carbonate)**
   e. NH_4OBr → **1 NH_4^+ + 1 $BrO^—$** **(Ammonium hypobromite)**
   f. $Mn(OH)_2$ → **1 Mn^{2+} + 2 $OH^—$** **(Manganese hydroxide)**

E2. C3a. Potassium chromate C3b. Ammonium sulfide C3c. Strontium sulfite

C4a. Cesium nitride C4b. Calcium dichromate C4c. Tin(IV) sulfate *or* stannic sulfate

E3: Carbon tetrabromide. Carbon is a nonmetal, so the compound is covalent (see Lesson 7A). Use *di-, tri-* prefixes in the names of *covalent* compounds. Practice recognizing the symbols of the nonmetals.

E4. a. Calcium bromide b. Nitrogen trichloride c. Sodium hydride

c. Copper(II) chloride or cupric chloride e. Rubidium perchlorate f. Potassium hypoiodite

g. Lithium phosphide h. Lead(II) oxide i. Ammonium bromite j. Sulfur dioxide

k. Calcium sulfite l. Tetraphosphorous trisulfide

Practice F

Ionic Compound NAME	SEPARATED Ions	SOLID Formula
Sodium chloride	$1\ Na^{+} + 1\ Cl^{-}$	$NaCl$
Aluminum sulfite	$2\ Al^{3+} + 3\ SO_3^{2-}$	$Al_2(SO_3)_3$
Lithium carbonate	**$2\ Li^{+} + CO_3^{2-}$**	**Li_2CO_3**
Potassium hydroxide	**$1\ K^{+} + 1\ OH^{-}$**	**KOH**
Silver nitrate	**1** Ag^{+} + **1** NO_3^{-}	**$AgNO_3$**
Ammonium sulfate	**2** NH_4^{+} + **1** SO_4^{2-}	**$(NH_4)_2SO_4$**
Iron(II) bromide/Ferrous bromide	**$1\ Fe^{2+} + 2\ Br^{-}$**	$FeBr_2$
Iron(III) sulfate/Ferric sulfate	**$2\ Fe^{3+} + 3\ SO_4^{2-}$**	$Fe_2(SO_4)_3$
Cuprous chloride	**$1\ Cu^{+} + 1\ Cl^{-}$**	**$CuCl$**
Tin(II) fluoride	**$1\ Sn^{2+} + 2\ F^{-}$**	**SnF_2**
Aluminum dichromate	**2** Al^{3+} **+ 3** $Cr_2O_7^{2-}$	**$Al_2(Cr_2O_7)_3$**
Potassium chromate	**$2K^{+} + CrO_4^{2-}$**	K_2CrO_4
Calcium carbonate	**$1\ Ca^{2+} + 1\ CO_3^{2-}$**	$CaCO_3$
Aluminum phosphate	**$1\ Al^{3+} + 1\ PO_4^{3-}$**	**$AlPO_4$**

Summary: Writing Names and Formulas

1. The name of an element is the name of its atoms.
2. In covalent bonds, electrons are shared. Two nonmetal atoms usually bond with a covalent bond.
3. An ionic bond exists between positive and negative ions. If a metal is bonded to a nonmetal, the bond is generally ionic. The metal is the positive ion.
4. Most compounds with all nonmetal atoms are covalent. Most compounds with one or more metal atoms and one or more nonmetal atoms are ionic.
5. A covalent compound has only covalent bonds. An ionic compound has one or more ionic bonds.
6. Naming binary covalent compounds:
    a. Names have two words. Compounds with H begin with *hydrogen*. Compounds with O end in (prefix)*oxide*. (This rule has precedence.)
    b. The first root word is the element farther to the left in the periodic table.
    c. For two atoms in the same column, the lower one is named first.
    d. The root of the second word is the root of the element name to the right, with a suffix *-ide*.
    e. The number of atoms is shown by a prefix.
        - *Mono-* = 1 atom. (For the first word of the name, *mono* is left off if it applies and assumed if no prefix is given.)
        - *Di-* = 2 atoms, *Tri-* = 3, *Tetra-* = 4, *Penta-* = 5, *Hexa-* = 6, *Hepta-* = 7, *Octa-* = 8.
7. Positive ions are cations (pronounced CAT-eye-ons). Negative ions are anions (pronounced ANN-eye-ons).
8. Metals can lose electrons to form positive ions. Column one elements form 1+ ions, column two elements form 2+ ions.
9. The name of a metal ion that forms only one ion is the name of the element.
10. Metals to the right of column two often form two or more cations. The name of these ions is
    - the element name followed by (I, II, III, or IV) stating the positive charge,
    - or a common name consisting of the Latin root plus *–ous* for the lower-charged ion or plus *–ic* for the higher-charged ion.
11. A polyatomic ion is composed of more than one atom.
12. The name of monatomic anions is the root followed by *-ide.*
13. For oxoanions of a given atom, the *per*–root–*ate*, root-*ate*, root-*ite*, and *hypo*-root-*ite* ions each have the same charge, but one fewer oxygens, respectively.

14. Ionic compounds have positive and negative ions in ratios that guarantee electrical neutrality.

15. To determine the names and formulas for ionic compounds,

    - write the separated-ions formula first, and
    - be certain that all names and formulas are electrically neutral.

16. To balance separated-ions formulas, add coefficients. Coefficients are numbers written in front of the ion symbols that show the ratio of the ions in the compound. In balancing, you may not change the symbol or the stated charge of an ion.

    (Coefficient times charge of cation) must equal (coefficient times charge of anion). The overall charge for ionic compounds must equal zero.

17. To write solid formulas for ionic compounds from their names, follow these steps.

    - Write the separated ions with the lowest whole-number coefficient ratios.
    - Write the two ion symbols, positive ion first, with*out* charges, a + sign, or coefficients.
    - *P*ut *p*arentheses () around *p*olyatomic ions IF you need more than one.
    - Make the separated formula coefficients into solid formula subscripts. Omit subscripts of 1.

18. To write separated ions from solid formulas,

    - decide the *negative* ion's charge and coefficients first.
    - Base the *positive* ion's charge on what balances atoms and charge.
    - Assume that metal atoms are monatomic (except for Hg_2^{2+}).

19. To name an ionic compound, name the ions, positive first.

* * * * *

# # # # #

*   *   *   *   *

NOTE on the Table of Elements.

The atomic masses in this Table of Elements use fewer significant figures than most similar tables in college textbooks. By "keeping the numbers simple," it is hoped that you will use "mental arithmetic" to do easy numeric cancellations and simplifications before you use a calculator for arithmetic.

Many calculations in these lessons have been set up so that you should not need a calculator at all to solve, if you look for *easy cancellations* first.

After any use of a calculator, use mental arithmetic and simple cancellations to *estimate* the answer, in order to catch errors in calculator use.

# # # # #

The ELEMENTS –

The **third** column shows the atomic number: The **protons** in the nucleus of the atom.

The **fourth** column is the molar mass, in **grams/mole**. For radioactive atoms, **( )** is the molar mass of most stable isotope.

Actinium	Ac	89	(227)
Aluminum	Al	13	27.0
Americium	Am	95	(243)
Antimony	Sb	51	121.8
Argon	Ar	18	39.95
Arsenic	As	33	74.9
Astatine	At	84	(210)
Barium	Ba	56	137.3
Berkelium	Bk	97	(247)
Beryllium	Be	4	9.01
Bismuth	Bi	83	209.0
Boron	B	5	10.8
Bromine	Br	35	79.9
Cadmium	Cd	48	112.4
Calcium	Ca	20	40.1
Californium	Cf	98	(249)
Carbon	C	6	12.0
Cerium	Ce	58	140.1
Cesium	Cs	55	132.9
Chlorine	Cl	17	35.5
Chromium	Cr	24	52.0
Cobalt	Co	27	58.9
Copper	Cu	29	63.5
Curium	Cm	96	(247)
Dysprosium	Dy	66	162.5
Erbium	Er	68	167.3
Europium	Eu	63	152.0
Fermium	Fm	100	(253)
Fluorine	F	9	19.0
Francium	Fr	87	(223)
Gadolinium	Gd	64	157.3
Gallium	Ga	31	69.7
Germanium	Ge	32	72.6
Gold	Au	79	197.0
Hafnium	Hf	72	178.5
Helium	He	2	4.00
Holmium	Ho	67	164.9
Hydrogen	H	1	1.008
Indium	In	49	114.8
Iodine	I	53	126.9
Iridium	Ir	77	192.2
Iron	Fe	26	55.8
Krypton	Kr	36	83.8
Lanthanum	La	57	138.9
Lawrencium	Lr	103	(257)
Lead	Pb	82	207.2
Lithium	Li	3	6.94
Lutetium	Lu	71	175.0
Magnesium	Mg	12	24.3
Manganese	Mn	25	54.9
Mendelevium	Md	101	(256)
Mercury	Hg	80	200.6
Molybdenum	Mo	42	95.9
Neodymium	Nd	60	144.2
Neon	Ne	10	20.2
Neptunium	Np	93	(237)
Nickel	Ni	28	58.7
Niobium	Nb	41	92.9
Nitrogen	N	7	14.0
Nobelium	No	102	(253)
Osmium	Os	76	190.2
Oxygen	O	8	16.0
Palladium	Pd	46	106.4
Phosphorus	P	15	31.0
Platinum	Pt	78	195.1
Plutonium	Pu	94	(242)
Polonium	Po	84	(209)
Potassium	K	19	39.1
Praseodymium	Pr	59	140.9
Promethium	Pm	61	(145)
Protactinium	Pa	91	(231)
Radium	Ra	88	(226)
Radon	Rn	86	(222)
Rhenium	Re	75	186.2
Rhodium	Rh	45	102.9
Rubidium	Rb	37	85.5
Ruthenium	Ru	44	101.1
Samarium	Sm	62	150.4
Scandium	Sc	21	45.0
Selenium	Se	34	79.0
Silicon	Si	14	28.1
Silver	Ag	47	107.9
Sodium	Na	11	23.0
Strontium	Sr	38	87.6
Sulfur	S	16	32.1
Tantalum	Ta	73	180.9
Technetium	Tc	43	(98)
Tellurium	Te	52	127.6
Terbium	Tb	65	158.9
Thallium	Tl	81	204.4
Thorium	Th	90	232.0
Thulium	Tm	69	168.9
Tin	Sn	50	118.7
Titanium	Ti	22	47.9
Tungsten	W	74	183.8
Uranium	U	92	238.0
Vanadium	V	23	50.9
Xenon	Xe	54	131.3
Ytterbium	Yb	70	173.0
Yttrium	Y	39	88.9
Zinc	Zn	30	65.4
Zirconium	Zr	40	91.2